# Measurement of the Absolute Drell-Yan Dimuon Cross Section in 800 GeV/c pp and pd Collisions

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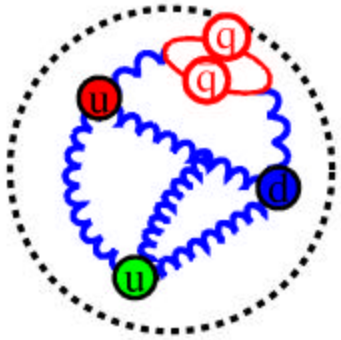
- Drell-Yan and Parton Distributions
- Fermilab E866/NuSea
- Absolute Cross Sections
- Future Experiments:  Fermilab E906

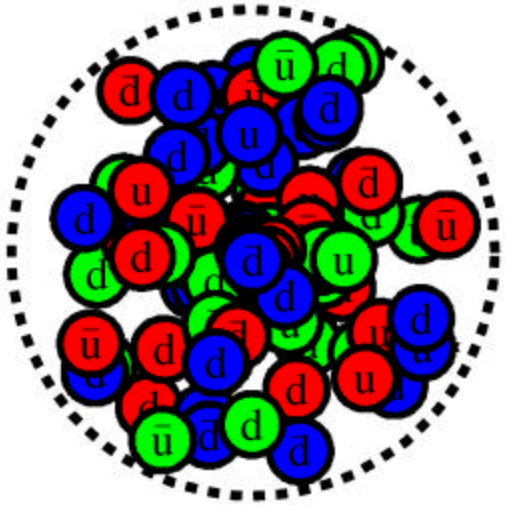
# Proton Constituents: Quarks and Gluons

- Naïve Proton:
  - 3 quarks at some $Q_0$, bound by gluons
  - QCD evolution does the rest



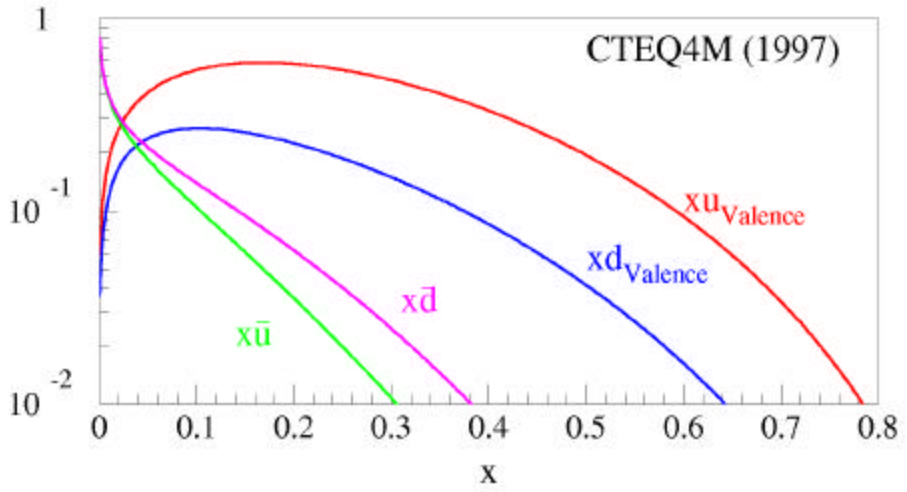

- Real Proton: **Data guides our knowledge**
  - Distribution of quarks, antiquarks and gluons
  - QCD evolution tells us how distribution evolves, but not original distributions
  - Experimental data provide guide for distributions
  - Theoretical assumptions guide (prejudice) our expectations of the Parton Distribution (PDF) behavior, *e.g.* Drell-Yan-West relationship

$$F(Q^2) \rightarrow (1/Q^2)^N \Rightarrow q(x) \rightarrow (1-x)^{2N-1}$$



# How are parton distributions determined?

- Phenomenological fit world's data to find parton distributions
  - MRST, Eur. Phys. J **C4**, 463 (1998)
  - CTEQ, Phys. Rev. **D55**, 1280 (1997)
  - GRSV, Phys. Rev. **D63**, 094005 (2001)
- Quite sophisticated
  - NNLO DIS, NLO Drell-Yan
  - include estimates of uncertainties in PDF's




## Deep Inelastic Scattering (DIS)

$$F_2^{mN}(x) \propto \sum_i e_i^2 x\left[q_i(x)+\bar{q}_i(x)\right]$$

$$F_2^{np}(x)+F_2^{np}(x) \propto \sum_i x\left[q_i(x)+\bar{q}_i(x)\right]$$

$$xF_2^{nN}(x) \propto \sum_i x\left[q_i(x)-\bar{q}_i(x)\right]$$

$$N^{p^\pm} \propto \sum_i e_i^2\left[q_i(x)D_{q_i}^{p^\pm}+\bar{q}_i(x)D_{\bar{q}_i}^{p^\pm}\right]$$

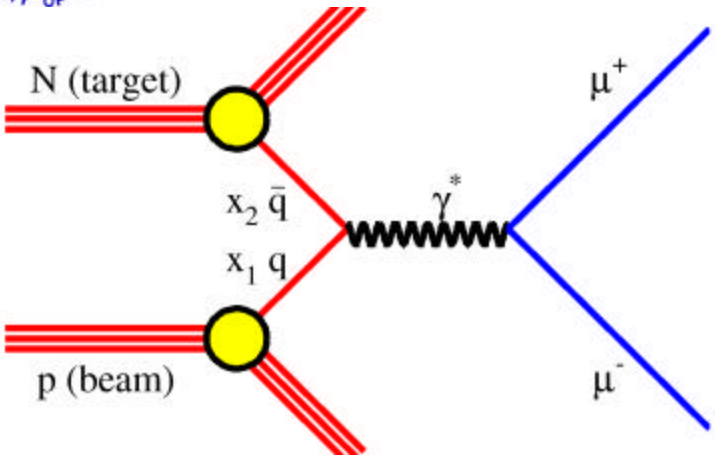
## W Production Asymmetry

$$A_W(y) \propto \frac{u(x_1)d(x_2)-d(x_1)u(x_2)}{u(x_1)d(x_2)+d(x_1)u(x_2)}$$

## Drell-Yan

$$\sigma_{DY} \propto \sum_i e_i^2\left[q_i(x_b)\bar{q}_i(x_t)+\bar{q}_i(x_b)q_i(x_t)\right]$$

# Drell-Yan $\mu^+\mu^-$ Production and PDF's




Leading Order

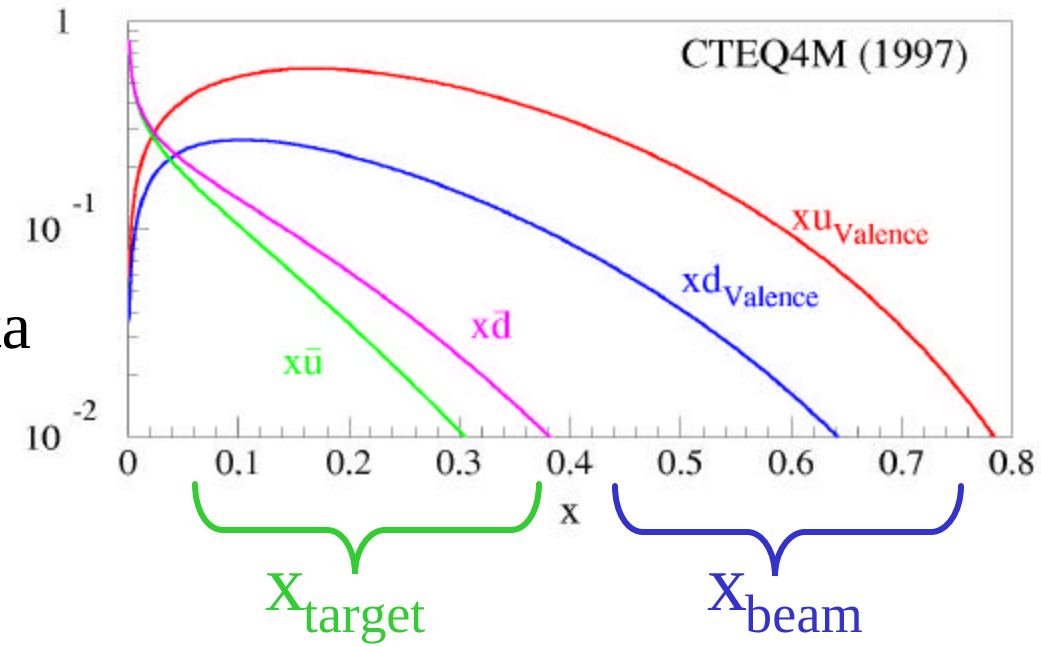
$$\frac{d^2\sigma}{dx_b dx_t} = \frac{4\pi\alpha^2}{9x_b x_t}\frac{1}{s}\times \sum_i e_i^2\left[q_{ti}(x_t)\bar{q}_{bi}(x_b) + \bar{q}_{ti}(x_t)q_{bi}(x_b)\right]$$

- Experiment measures μ momenta

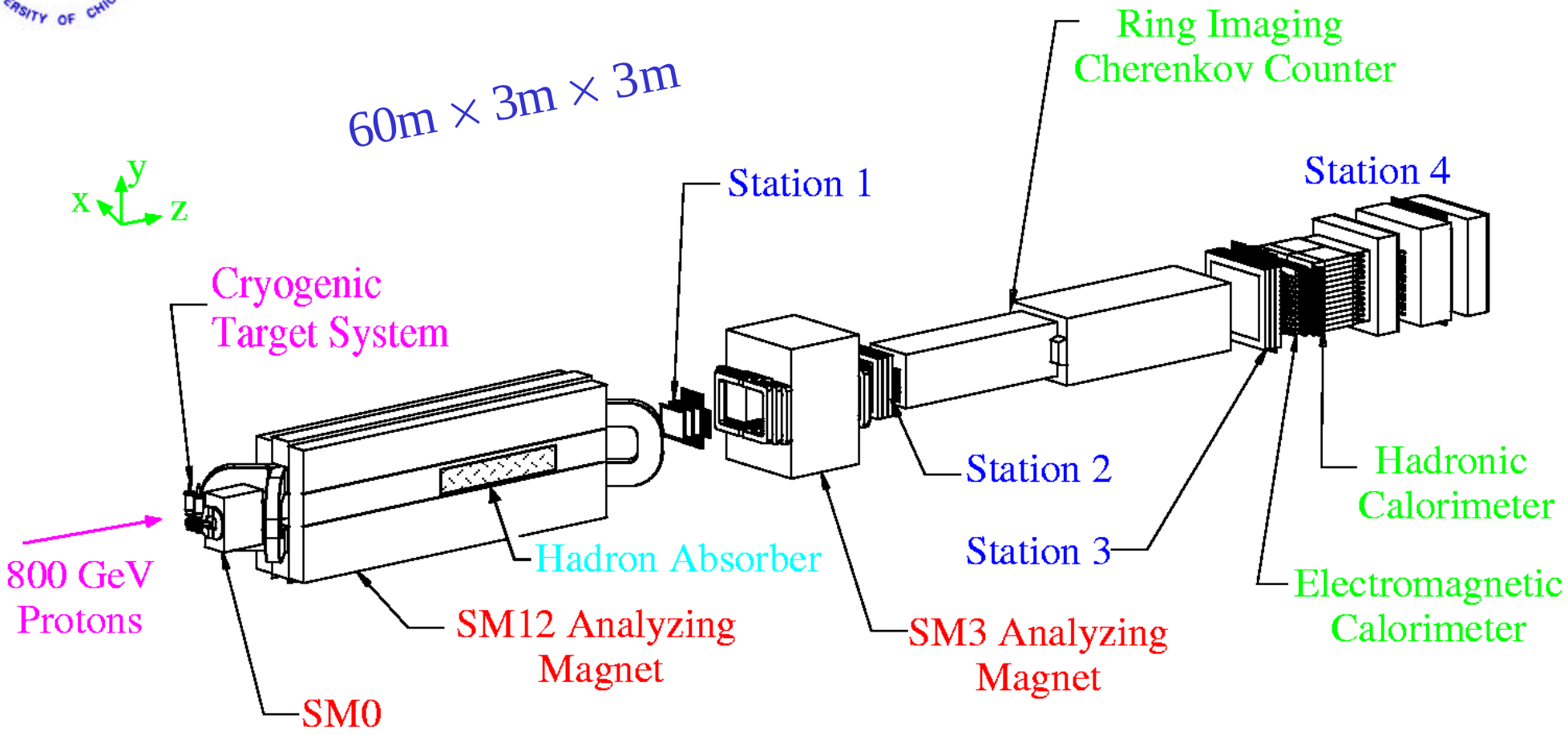
$\Rightarrow$ Virtual photon $p_L$ and $p_T$

$$x_F \approx 2p_L/\sqrt{s} = x_b - x_t$$
$$M^2_{\mu^+\mu^-} = s x_b x_t$$

- Detector acceptance chooses range in $x_{target}$ and $x_{beam}$.
- $x_F = x_{beam} - x_{target} > 0$
- high-x Valence Beam quarks
- Low-x sea quarks.



# Fermilab E866/NuSea Detector




- Forward $x_F$, high mass μ-pair spectrometer
- Liquid hydrogen and deuterium targets
- Two acceptance defining magnets (SM0, SM12)
- Beam dump (4.3m Cu)
- Hadronic absorber (13.4 $I_0$-Cu, C, $CH_2$)
- Momentum analyzing magnet (SM3)
- Three tracking stations
- Muon identifier wall & 4th tracking

# FNAL E866/NuSea Collaboration

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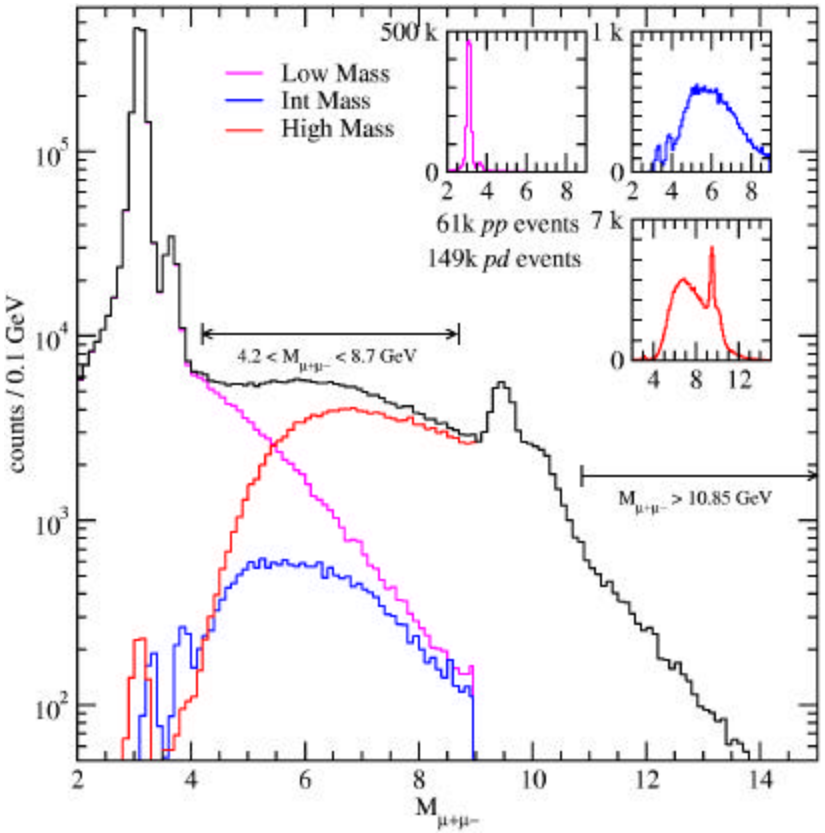
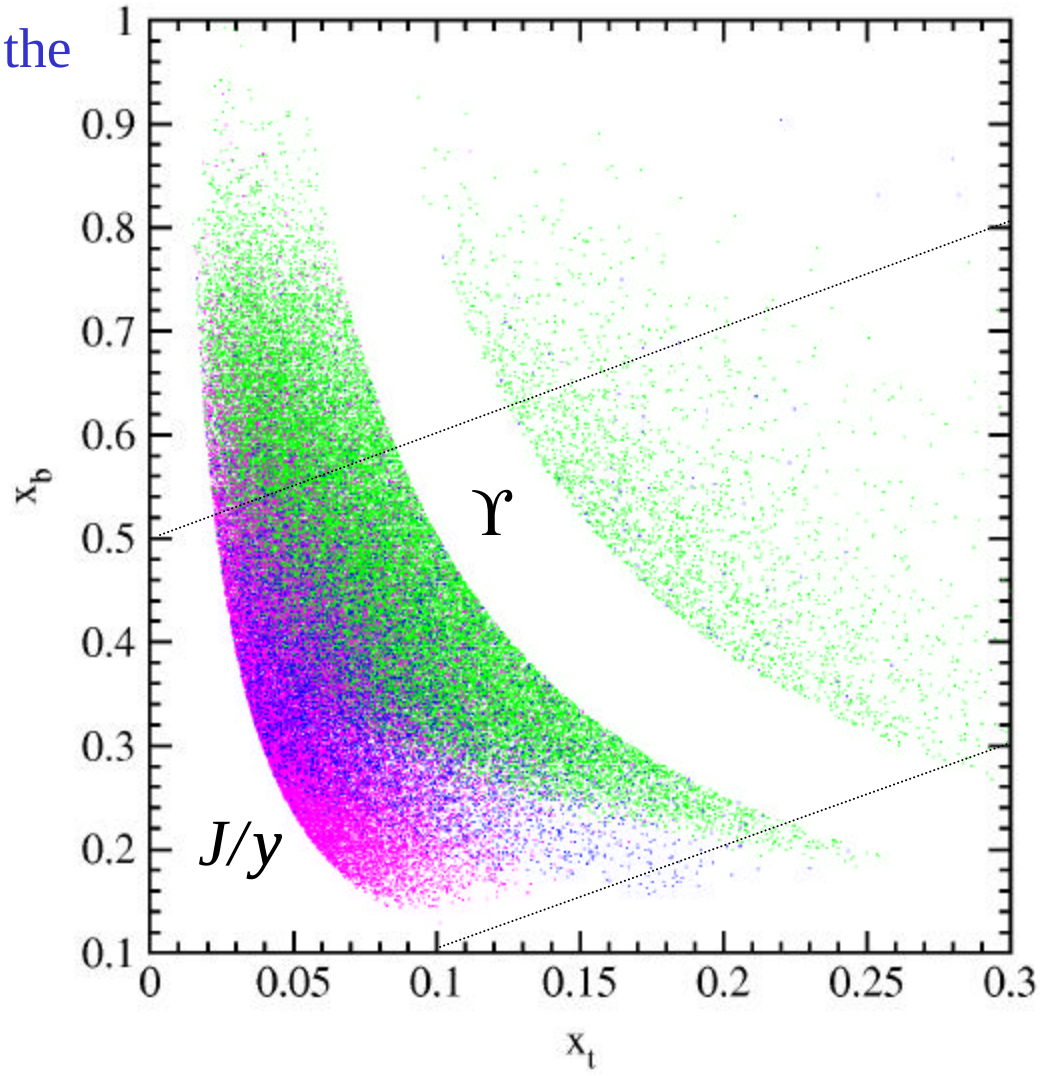
# The Data Sample

- 3 spectrometer magnet setting which focus different muon pair masses into the detector: low, intermediate and high



# E866 quark sea distributions: $\bar{d}/\bar{u}$

- Select $x_b \gg x_t$ to get first term (detector acceptance does this).

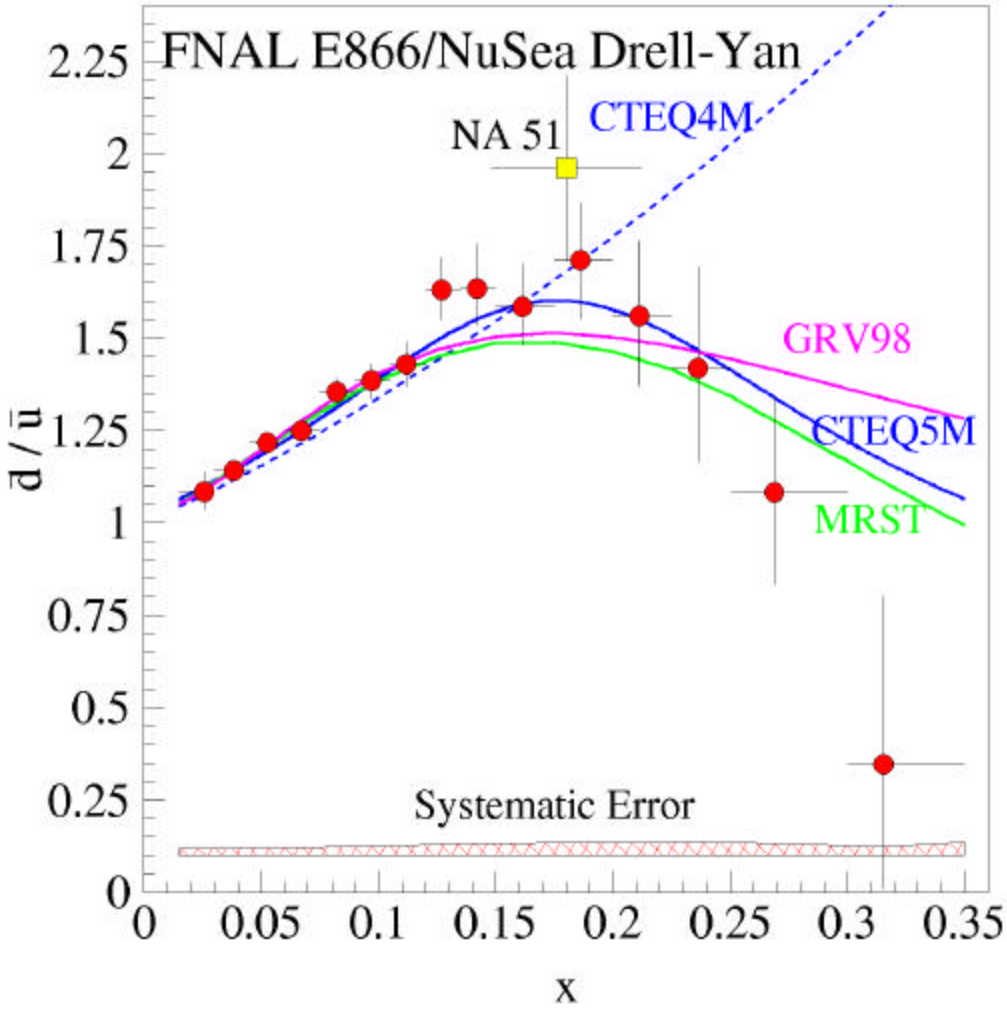
$$\sigma_{DY} \propto \sum_i e_i^2 \left[\bar{q}_{ti}(x_t) q_{bi}(x_b) + q_{ti}(x_t)\bar{q}_{bi}(x_b)\right]$$

- Study ratio of deuterium to hydrogen

$$\left.\frac{\sigma^{pd}}{2\sigma^{pp}}\right|_{x_b \gg x_t} \approx \frac{1}{2}\left[1 + \frac{\bar{d}(x_t)}{\bar{u}(x_t)}\right]$$

(Actually use full NLO calculation to extract sea quark ratio)

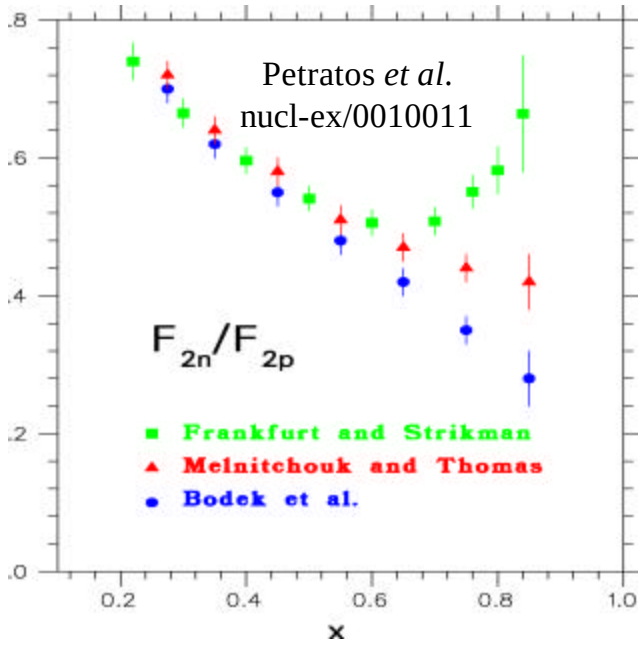
- Approx. 360,000 events.

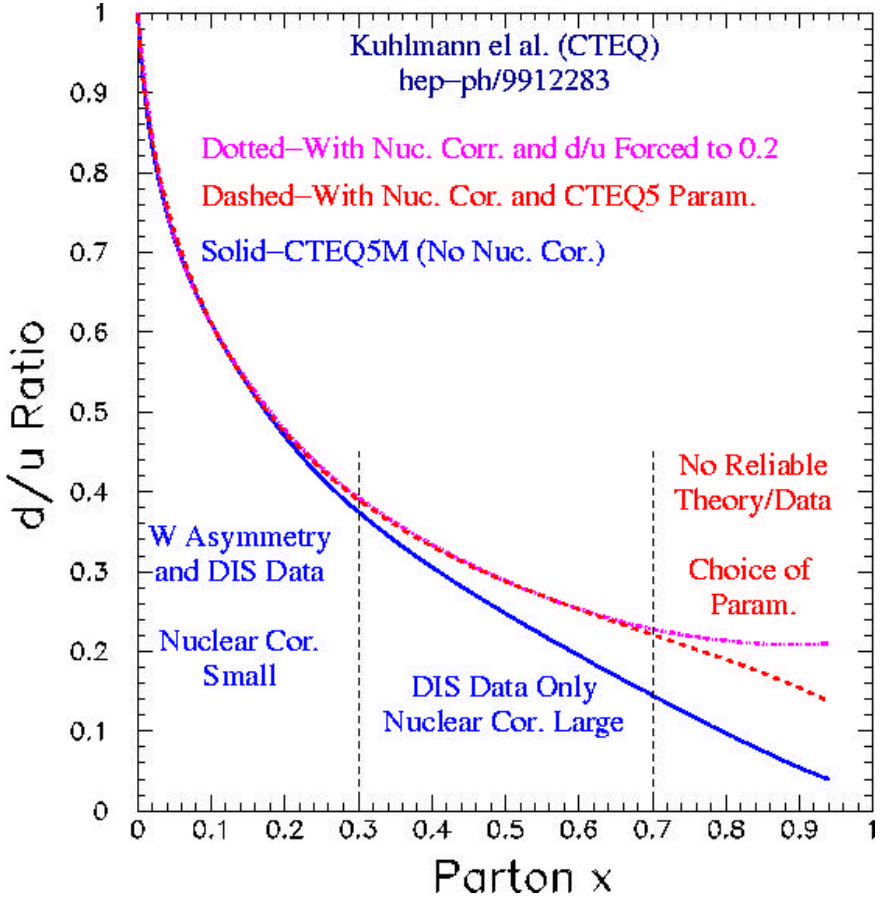


# Proton Valence Structure: d/u as x→ 1

## Theory

- Exact SU(6):
  d/u → 1/2
- Diquark S=0 dominance:
  d/u → 0
- pQCD:
  d/u → 3/7

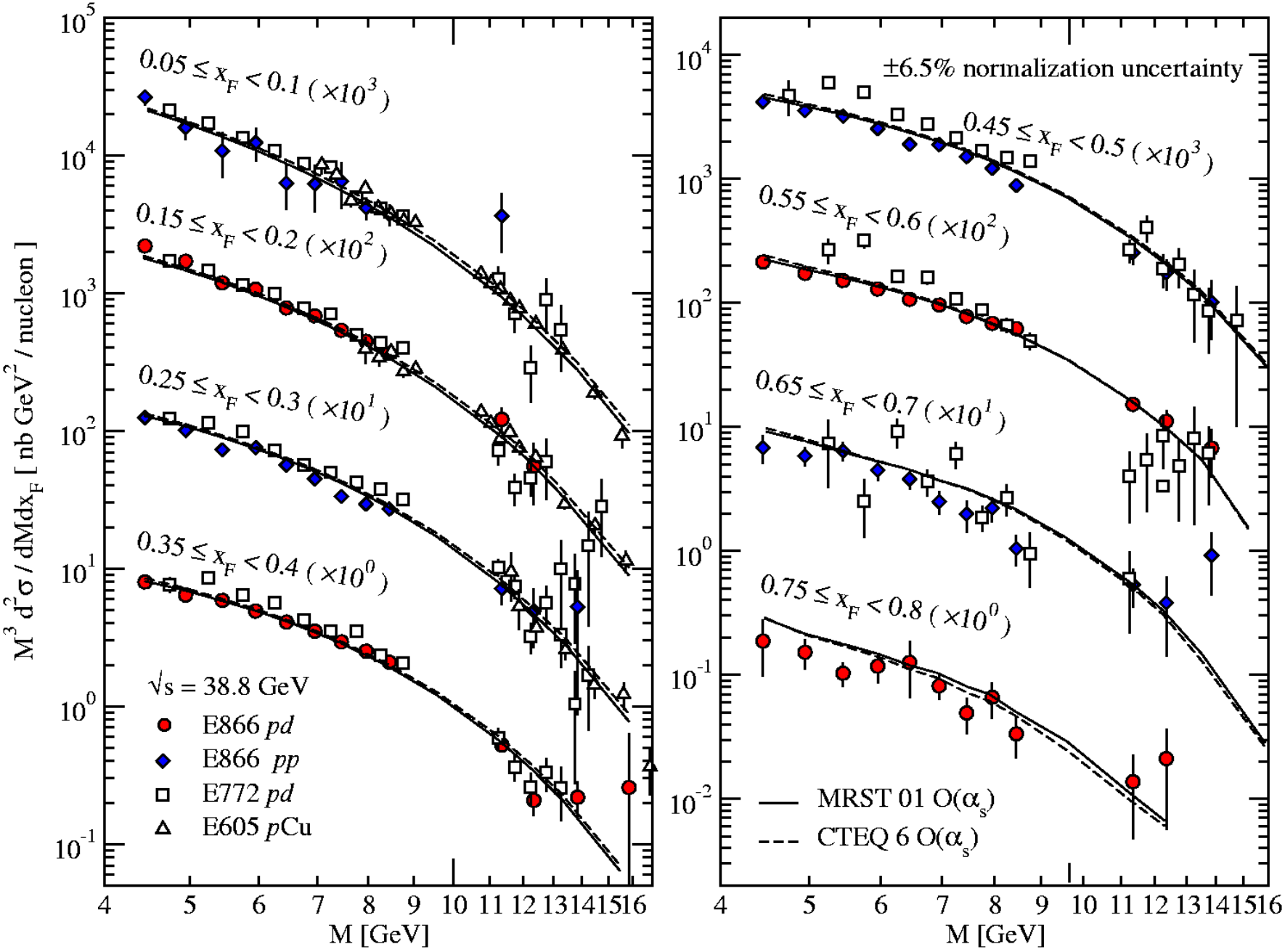


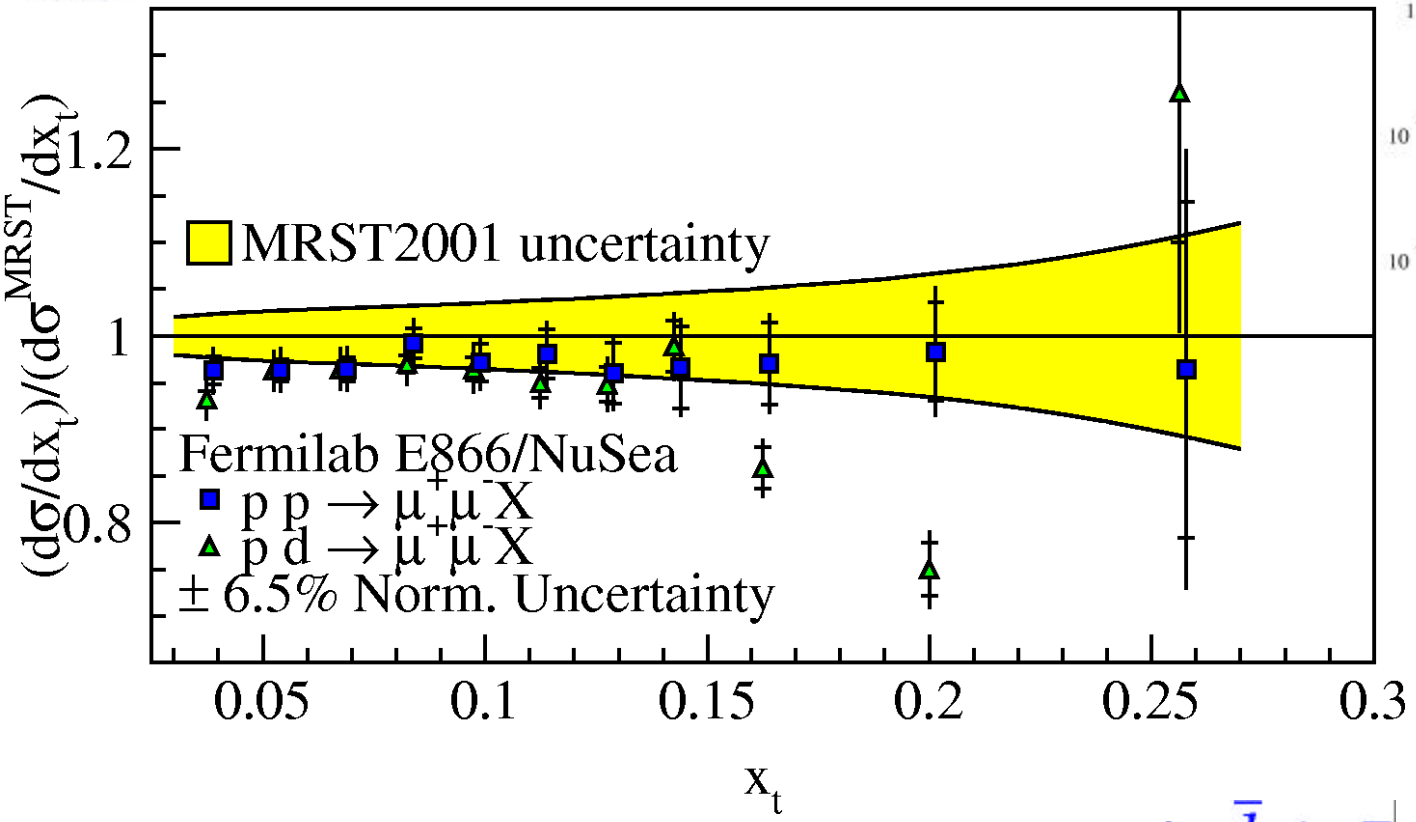

## Data

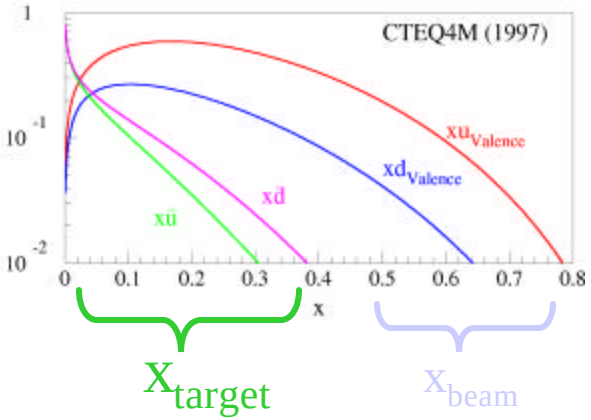
- Nuclear binding/Fermi Motion effects in deuterium—choice of treatments.
- ***Proton data is needed.***

# Drell Yan Absolute Cross Sections



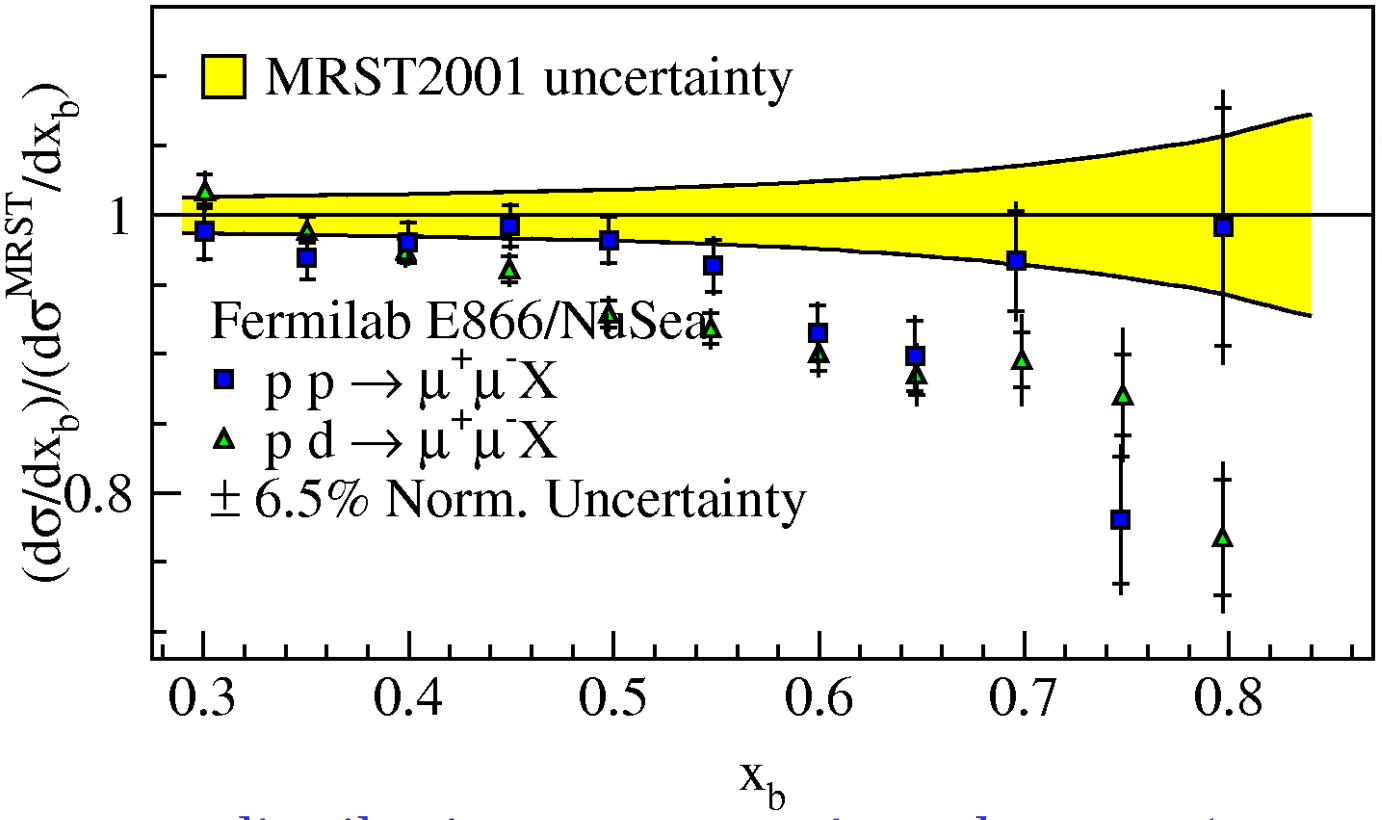
# $x_{target}$ NLO comparison (Sea)

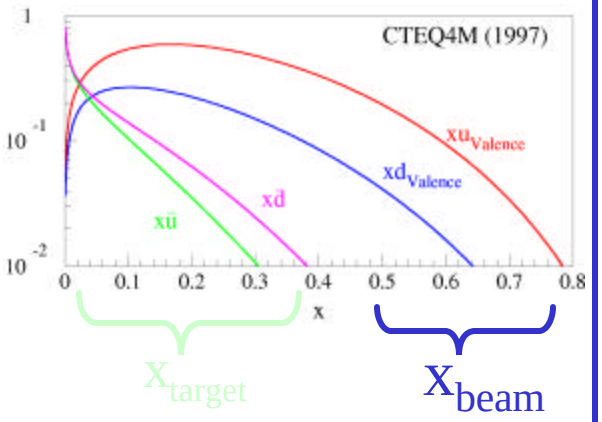


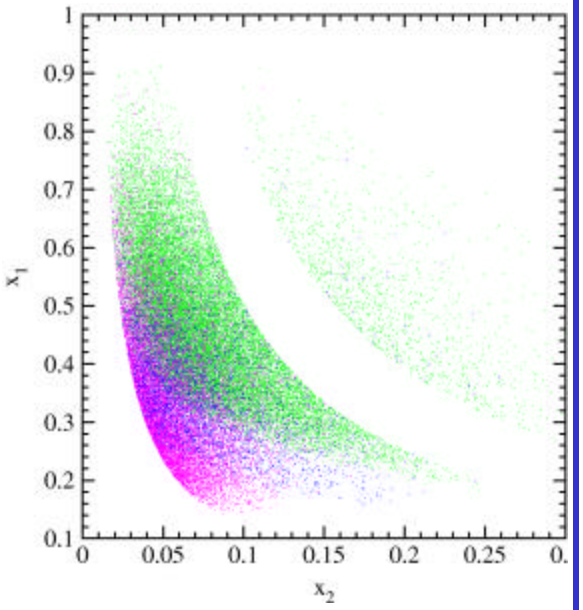




- $x_{target}$ distribution measures magnitude of $\bar{d} + \bar{u}$
- Data in good agreement with PDF's for x < 0.15. Deuterium starts to fall off above x = 0.15
- Sea previously set by HERA small-x data and E605 Drell-Yan. Present data is much more precise.

# $x_{beam}$ NLO comparison (Valence)

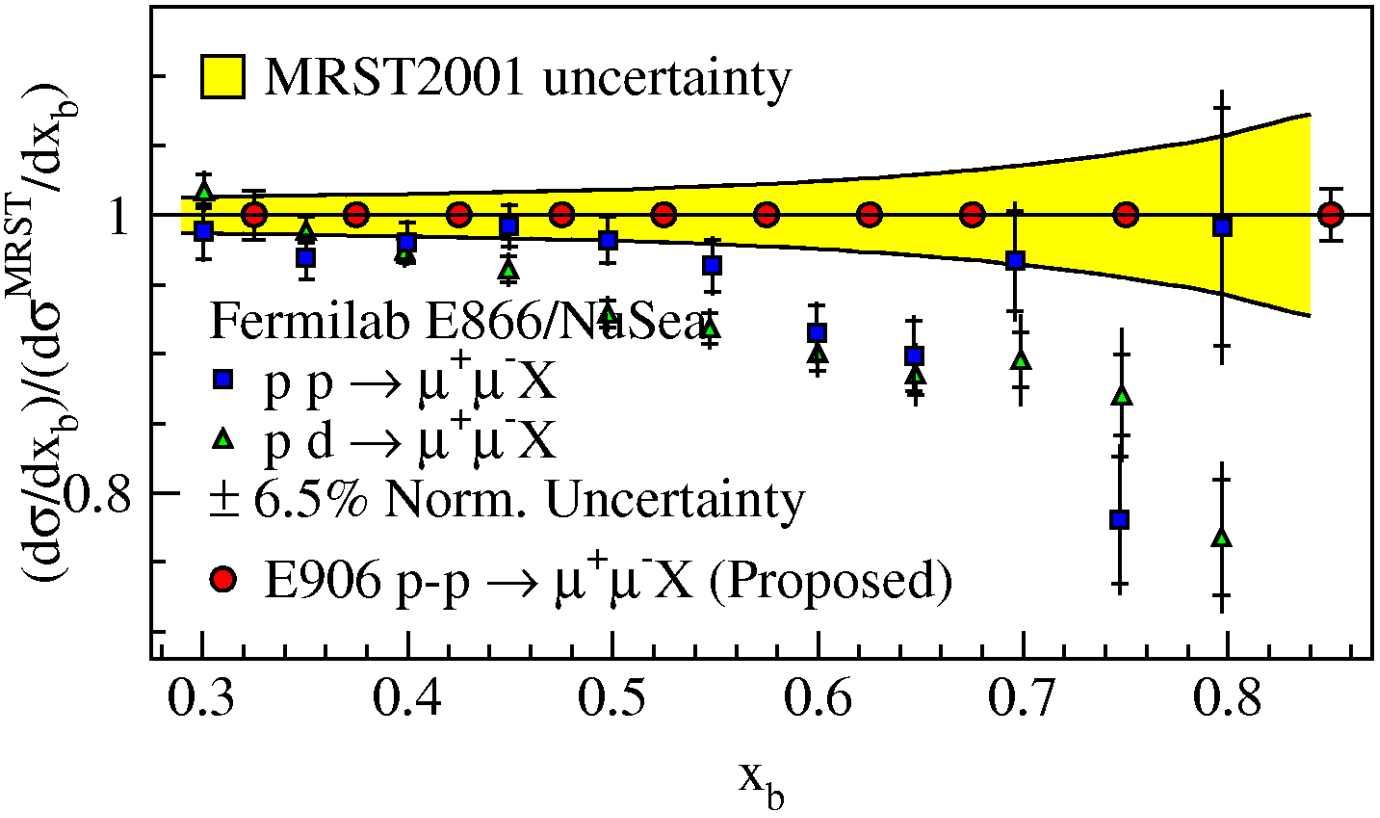



- $x_{beam}$ distribution measures *4u + d* as *x*→ *1*.
- Both MRST and CTEQ *overestimate* valence distributions as *x*→ *1* by 15-20%.
- Possibly related to *d/u* ratio as *x* → *1*, but requires full PDF-style fit.
- Working with CTEQ to incorporate data in global fit.
- *Radiative corrections under study.*

# Future Drell-Yan at Fermilab: E906

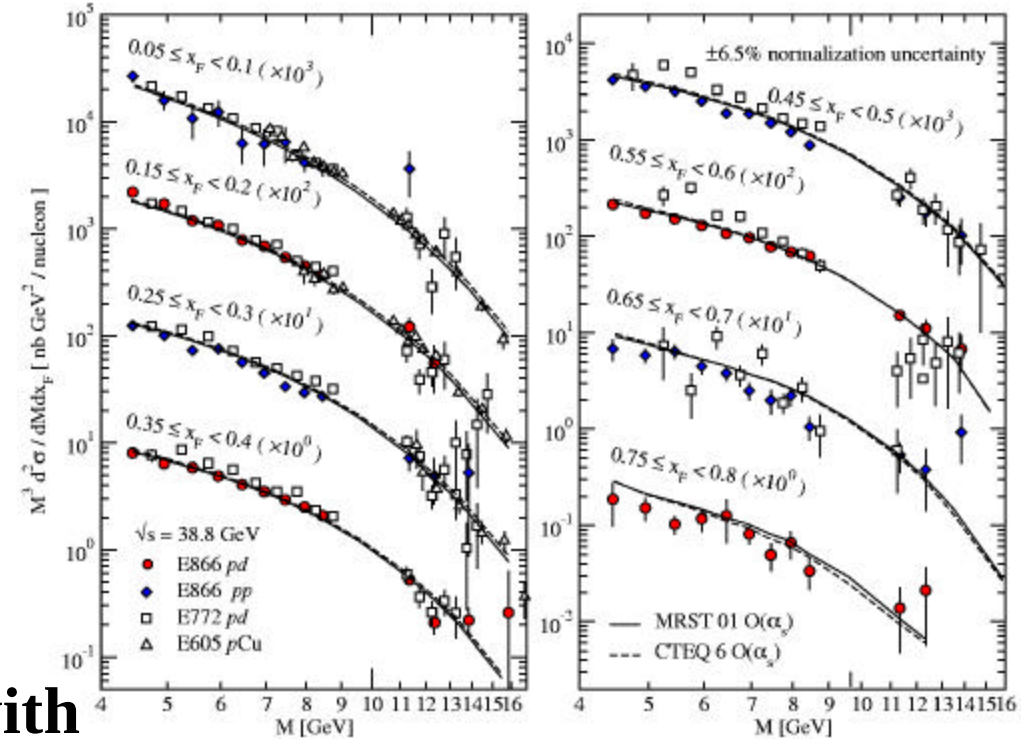



Fermilab E906 will:

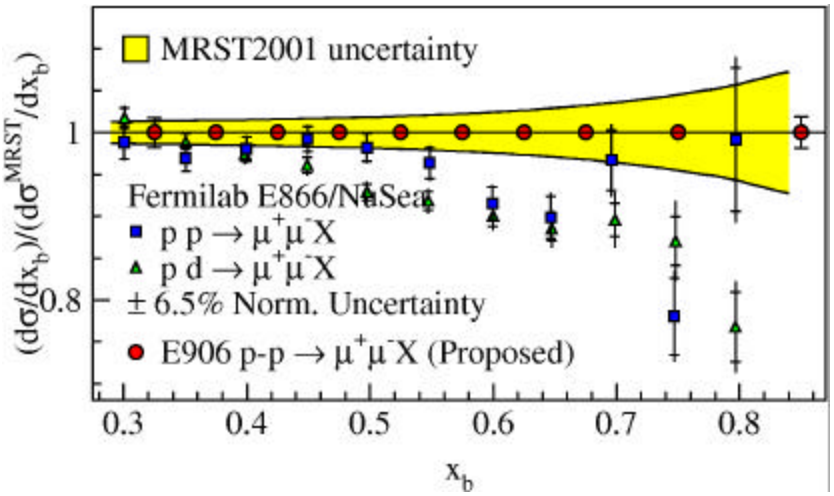
- Provide proton absolute σ at high-x
- $\bar{d}/\bar{u}$ $0.1 \leq x \leq 0.45$
- Nuclear dependence of antiquark sea

- Fixed-target Drell-Yan with 120 GeV Fermilab Main Injector
- $\sigma_{DY} \propto 1/s \Rightarrow$ Larger cross section (more statistics)
- Scheduled to start collecting data in late 2008

# Summary: Drell-Yan Cross Sections and Proton Parton Distributions




- **Fermilab E866 has measured the Drell-Yan Cross section with 800 GeV pp and pd interactions.**
- **Data are in good agreement with previous Drell-Yan data.**
- **Proton structure**
  - d and u as $x \rightarrow 1$: current PDF's seem to overestimate valence distributions.
  - d-bar and u-bar at intermediate x: current PDF's in agreement with data




- **The Future: E906**
  - Significant increase in Physics reach over previous Drell-Yan experiments.
  - Approved in 2001/most likely run in 2008

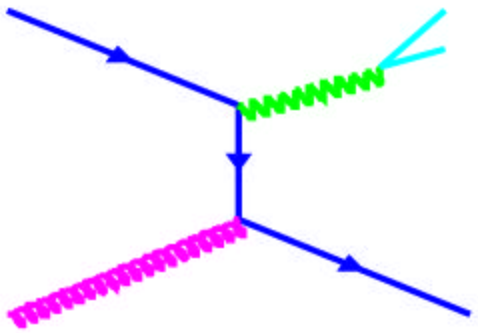
# Data vs. PDF comparison

$K'_{px} = \sigma_{data}/\sigma_{NLO}$

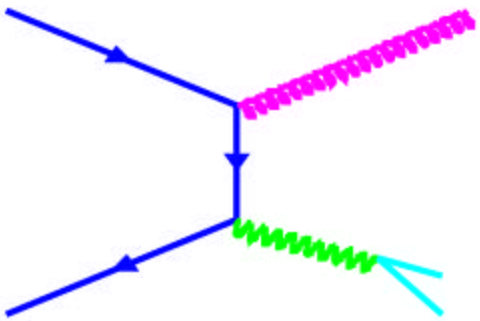
| PDF | $K'_{pp}$ | $\chi^2$/dof | $K'_{pd}$ | $\chi^2$/dof |
|---|---|---|---|---|
| CTEQ5 | 0.976 | 1.42 | 0.963 | 2.51 |
| **CTEQ6** | **1.016** | **1.39** | **1.001** | **2.56** |
| MRST98 | 0.973 | 1.38 | 0.960 | 2.37 |
| **MRST2001** | **0.980** | **1.45** | **0.966** | **2.44** |
| GRV98 | 0.811 | 2.04 | 0.808 | 4.15 |

- Reasonable overall agreement with recent Next-to-Leading Order parton distribution fits.
- $\pm$ 6.5% global normalization uncertainty not included in fit.

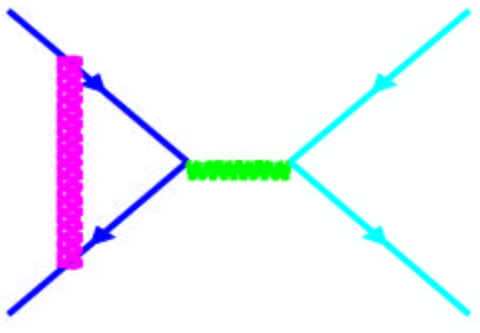
# Drell-Yan: NLO Terms



Compton Scattering

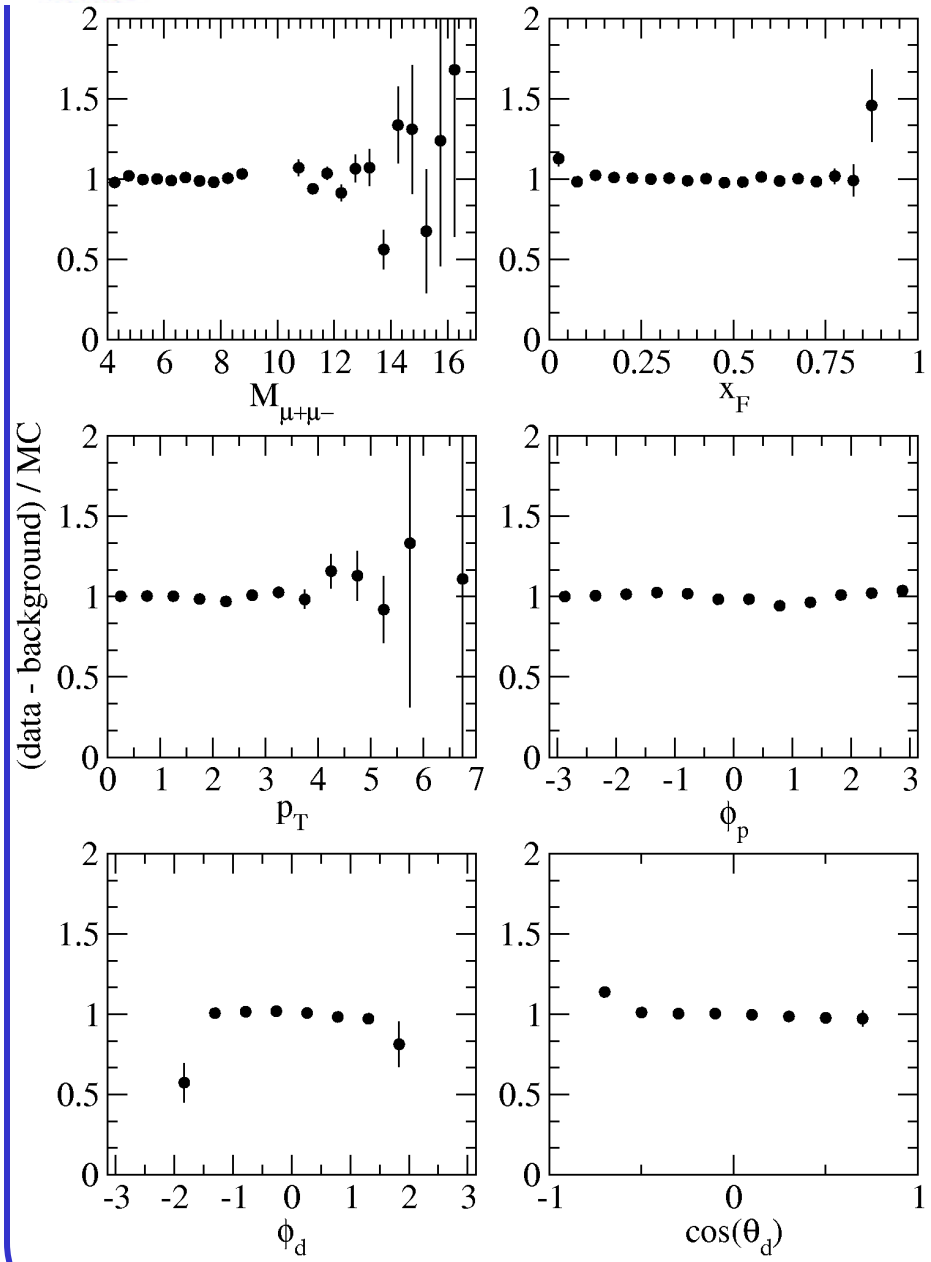


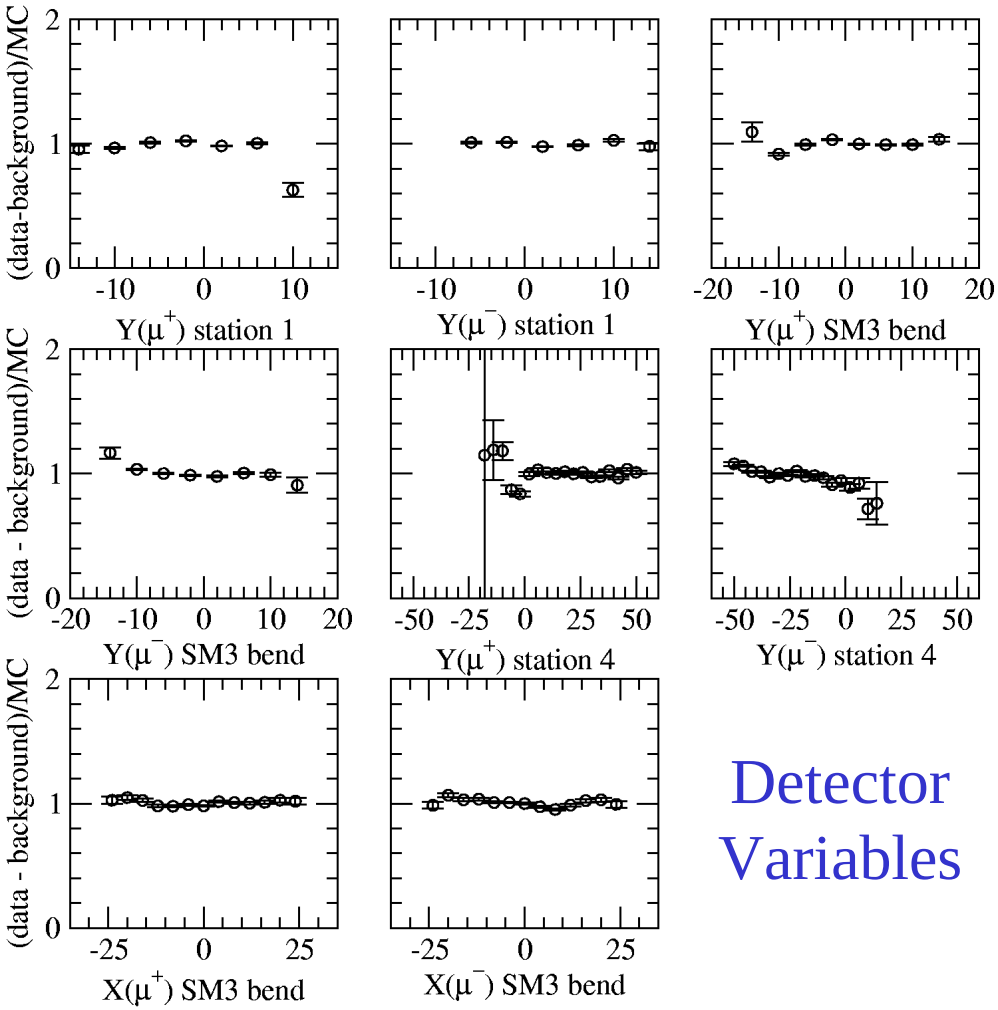
Annihilation



Gluon Vertex Correction

# Monte Carlo Acceptance




Detector Variables

Physics Variables

# E $d^3\sigma/dp^3$ E866 and E772